# Simulating and Analysing Crystal Channelling in the Large Hadron Collider



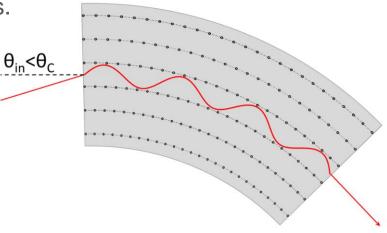
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Skidmore College CERN Summer Student Programme



## What is Crystal Collimation?

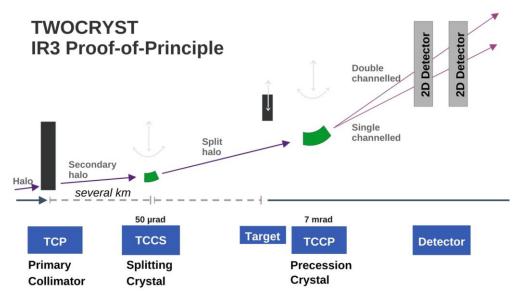
- A type of advanced **beam cleaning** that uses bent silicon crystals to steer beam halo particles toward an absorber
- When charged particles interact with a crystal at the right impact conditions, they become trapped and **oscillate in the potential well** generated by neighboring crystalline planes.
- This phenomenon is called "channeling."



## What is Crystal Collimation?

The Non-linear Dynamics and Collimation (NDC) section uses bent silicon crystals to channel beam halo particles in the Large Hadron Collider

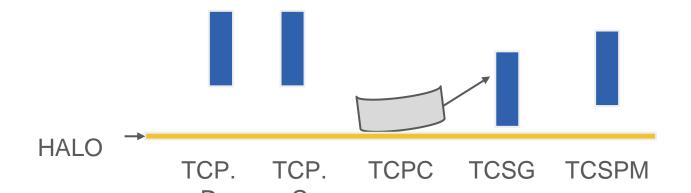
- Particularly useful for channeling lead ion beams-the crystal applies the same steering angle for intact lead ions and fragments.
  - This is why crystal collimation is being implemented for the High Luminosity-LHC project to improve the ion collimation cleaning efficiency!



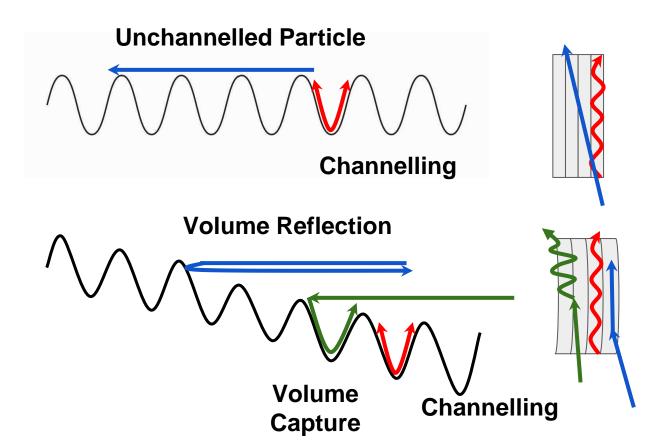
## What I am doing: a change since the first talk!

• For my project, I am using the simulation program **SixTrack** to simulate the results of a recent **Machine Development (MD)** study in the LHC from May 15th, 2024, which focused on testing and arrangement of the collimator/crystal hierarchy.

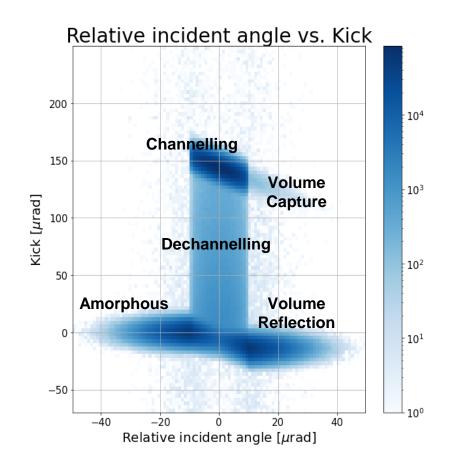
First step: develop and test an analysis algorithm, which calculates the channeling efficiency, or the percent of particles channeled by the crystal.



Phenomena from Crystal Particle Interactions

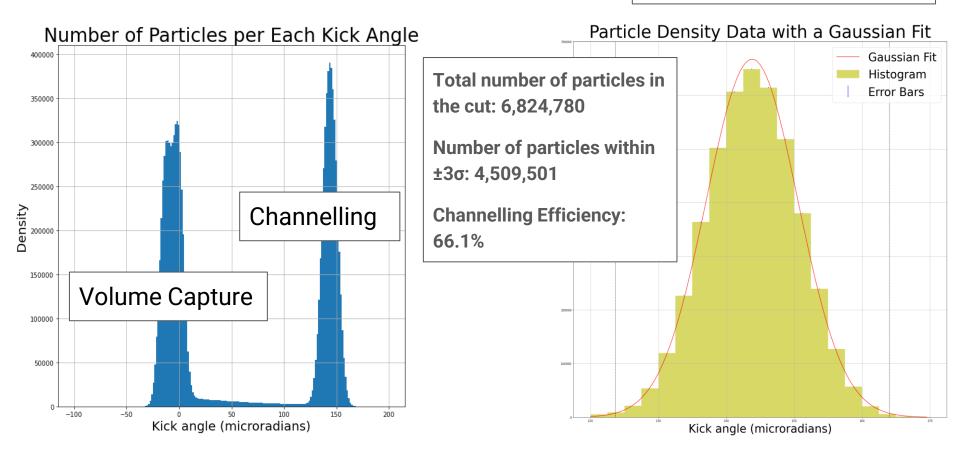


### **Recognizing Phenomena**



## Finding the Channelling Efficiency

±10 µrad cut on the proton incident angle is applied



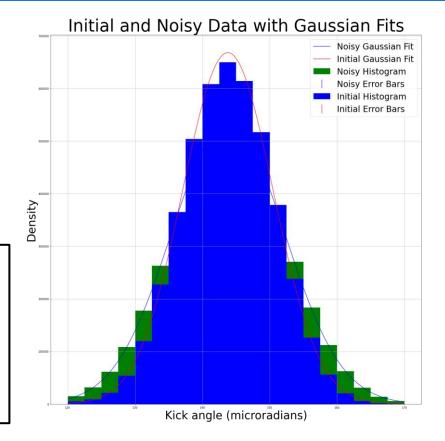
## **Including Resolution**

- I added an experimental resolution by adding random gaussian noise to the simulated deflections at the same level that noise occurs in the experiment.
- You can see the added resolution in green!

Total number of particles in the cut: 6,824,780

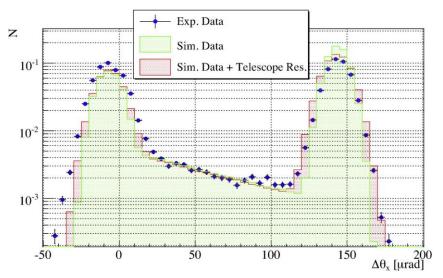
Number of particles within ±3o: 4520869

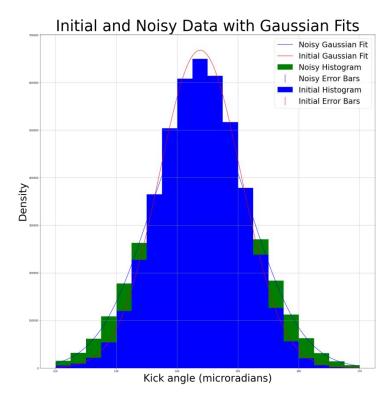
**Channelling Efficiency: 66.2%** 



#### Conclusions

I found that the results of my simulation analysis match up well with results from a corresponding NDC paper, which validates this simulation tool and my analysis script for this MD.





#### Next Steps

- I am currently using SixTrack to simulate a test of a TCPC crystal in the LHC.
  - I have completed the first simulation using particles at 450 GeV and will repeat the process considering crystal channeling at higher energies of 1 TeV, 3 TeV, and 5 TeV.
- Using the analysis script described here to find the channeling efficiency at each energy, so it can be compared to the collected data from the MD measurements.

|  | ch/work/f/fwharton/public/01_4 | 150gev/clean_input —   | ssh fw   | harton@lxplus  | .cern.ch   |   |
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| SIG FAM tctv1  | 999.0 TERTIARY                 |  |  |  |  |   |
| NSIG FAM tcth2   | 999.0 TERTIARY                 |  |  |  |  |   |
| NSIG_FAM tctv2   | 999.0 TERTIARY                 |  |  |  |  |   |
| NSIG_FAM tcth5   | 999.0 TERTIARY                 |  |  |  |  |   |
| NSIG_FAM tctv5   | 999.0 TERTIARY                 |  |  |  |  |   |
| NSIG_FAM tcth8   | 999.0 TERTIARY                 |  |  |  |  |   |
| NSIG_FAM tctv8   | 999.0 TERTIARY                 |  |  |  |  |   |
| # Physics debris   |                                |  |  |  |  |   |
| NSIG_FAM tcl4  | 999.0 TERTIARY                 |  |  |  |  |   |
| NSIG_FAM tc15  | 999.0 TERTIARY                 |  |  |  |  |   |
| NSIG_FAM tcl6  | 999.0 TERTIARY                 |  |  |  |  |   |
| <pre>Physics debris in AL:</pre>   | ICE (only for ions)            |  |  |  |  |   |
| NSIG_FAM tcld  | 999.0 TERTIARY                 |  |  |  |  |   |
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| ######### Collimato:   |                                |  |  |  |  |   |
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| cl.411.b2  |                                | tcl4 CU  |  |  | 0.0  | 0.  |
| cl.511.b2  |                                | tcl5 CU  |  |  | 0.0  | 0.  |
|  |                                |  |  | 1.000 6  | 0.0  |   |
| tcl.611.b2   |                                | tcl6 Iner  |  | 1.000 6  |  | 0.  |
|  |                                | tcio iner<br>tcth8   |  | 1.000  | 0.0  | 0.  |
| tctph.4r8.b2<br>tctpv.4r8.b2   |                                | tcth8<br>tctv8   | Iner<br>Iner   | 1.000  | 0.0<br>90.0  | 0.<br>0.  |
| tctph.4r8.b2<br>tctpv.4r8.b2<br>tdisa.a4r8.b2  |                                | tcth8<br>tctv8<br>tdi  | Iner<br>Iner<br>CU   | 1.000<br>1.000<br>1.565  | 0.0<br>90.0<br>90.0  | 0.<br>0.<br>0.  |
| cctph.4r8.b2<br>cctpv.4r8.b2<br>cdisa.a4r8.b2<br>cdisb.a4r8.b2   |                                | tcth8<br>tctv8<br>tdi<br>tdi   | Iner<br>Iner<br>CU<br>CU   | 1.000<br>1.000<br>1.565<br>1.565   | 0.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.  |
| ctph.4r8.b2<br>ctpv.4r8.b2<br>disa.a4r8.b2<br>disb.a4r8.b2<br>disb.a4r8.b2   |                                | tcth8<br>tctv8<br>tdi<br>tdi<br>tdi  | Iner<br>Iner<br>CU<br>CU<br>CU   | 1.000<br>1.000<br>1.565<br>1.565<br>1.565  | 0.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.  |
| tctph.4r8.b2<br>tctpv.4r8.b2<br>tdisa.a4r8.b2<br>tdisb.a4r8.b2<br>tdisc.a4r8.b2<br>tclia.4r8.b2<br>tclia.418   |                                | tcth8<br>tctv8<br>tdi<br>tdi<br>tdi<br>tcli  | Iner<br>Iner<br>CU<br>CU<br>CU<br>CU<br>CU   | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.665<br>1.000  | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.  |
| tctph.4r8.b2<br>tctpv.4r8.b2<br>tdisa.a4r8.b2<br>tdisb.a4r8.b2<br>tdisc.a4r8.b2<br>tclia.418<br>tclia.418<br>tclib.618.b2  |                                | tcth8<br>tctv8<br>tdi<br>tdi<br>tdi<br>tcli<br>tcli  | Iner<br>CU<br>CU<br>CU<br>CU<br>C<br>C   | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>1.000  | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.  |
| <pre>tcl.61.b2 tctph.4r8.b2 tctpt.4r8.b2 tdiss.a4r8.b2 tdiss.a4r8.b2 tdist.a4r8.b2 tclis.4r8.b2 tclis.618.b2 tclib.618.b2 tcp.d677.b2</pre>  |                                | tcth8<br>tctv8<br>tdi<br>tdi<br>tcli<br>tcli<br>12.9   | Iner<br>CU<br>CU<br>CU<br>C<br>C<br>C<br>MoGR  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>1.000<br>0.600   | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.                                    |
| <pre>tctph.4r8.b2<br/>tctpv.4r8.b2<br/>ddisa.a4r8.b2<br/>tdisa.a4r8.b2<br/>tdisc.a4r8.b2<br/>tclia.4l8<br/>tclib.6l8.b2<br/>tcp.d6r7.b2<br/>tcp.c6r7.b2</pre>  |                                | tcth8<br>tctv8<br>tdi<br>tdi<br>tcli<br>tcli<br>12.9<br>10.9   | Iner<br>Iner<br>CU<br>CU<br>CU<br>C<br>C<br>MoGR<br>MoGR   | 1.000<br>1.000<br>1.565<br>1.565<br>1.665<br>1.000<br>1.000<br>0.600<br>0.600  | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.                              |
| <pre>ctph.4r8.b2 ddisa.a4r8.b2 ddisa.a4r8.b2 ddisb.a4r8.b2 rdisb.a4r8.b2 rclia.418 rclib.618.b2 rclib.618.b2 rclib.618.b2 rclib.618.b2 rclib.618.b2 rclib.618.b2</pre>   |                                | tcth8<br>tctv8<br>tdi<br>tdi<br>tcli<br>tcli<br>12.9<br>10.9<br>tcp7   | Iner<br>CU<br>CU<br>CU<br>C<br>C<br>MoGR<br>MoGR<br>C  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>1.000<br>0.600<br>0.600<br>0.600   | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.                              |
| ctph.4r8.b2<br>ctpv.4r8.b2<br>disb.a4r8.b2<br>disb.a4r8.b2<br>clis.4r8.b2<br>clis.618.b2<br>cc, d6r7.b2<br>cp.6dr7.b2<br>cp.6dr7.b2<br>cp.6dr7.b2<br>csg.a6r7.b2   |                                | tcth8<br>tctv8<br>tdi<br>tdi<br>tcli<br>tcli<br>12.9<br>10.9<br>tcp7<br>tcsp7  | Iner<br>CU<br>CU<br>CU<br>C<br>MoGR<br>MoGR<br>C<br>C  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>1.000<br>0.600<br>0.600<br>0.600<br>1.000  | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.            |
| ctph.478.b2<br>ctpv.478.b2<br>diss.4478.b2<br>diss.4478.b2<br>diss.4478.b2<br>clis.418<br>clib.618.b2<br>cp.dd7.b2<br>cp.c677.b2<br>cp.b677.b2<br>csg.b677.b2<br>csg.b677.b2   |                                | tcth8<br>tctv8<br>tdi<br>tdi<br>tcli<br>tcli<br>12.9<br>10.9<br>tc9<br>tcs9<br>tcs9<br>tcs9  | Iner<br>Iner<br>CU<br>CU<br>CU<br>C<br>C<br>MoGR<br>MoGR<br>C<br>C<br>C  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>1.000<br>0.600<br>0.600<br>0.600<br>1.000<br>1.000   | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.                  |
| <pre>ctph.4r8.b2<br/>ctpv.4r8.b2<br/>dis.a4r8.b2<br/>dis.a4r8.b2<br/>disc.a4r8.b2<br/>clis.418<br/>clib.618.b2<br/>cp.66r7.b2<br/>cp.66r7.b2<br/>cp.66r7.b2<br/>csg.a5r7.b2<br/>csg.a5r7.b2</pre>  |                                | tcth8<br>tctv8<br>tdi<br>tdi<br>tcli<br>tcli<br>12.9<br>10.9<br>tcp7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7   | Iner<br>Iner<br>CU<br>CU<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C   | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>0.600<br>0.600<br>0.600<br>1.000<br>1.000  | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8 |
| crtph.4r8.b2<br>crtp.4r8.b2<br>dis.4r8.b2<br>dis.4r8.b2<br>dis.4r8.b2<br>cris.4r8.b2<br>cris.4r8.b2<br>cris.4r8.b2<br>cris.618.b2<br>cris.618.b2<br>cris.618.b2<br>cris.618.b2<br>cris.617.b2<br>creg.b577.b2<br>creg.b577.b2<br>creg.5577.b2<br>creg.ds77.b2  |                                | <pre>tctN8 tctv8 tdi tdi tdi tdi tcli tcli tcli tcli tcli tcsg7 tcsg7 tcsg7 tcsg7 tcsg7</pre>  | Iner<br>Iner<br>CU<br>CU<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>MoGR   | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>0.600<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000   | 6.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>0.0   | 8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8 |
| <pre>ctph.4r8.b2<br/>ctpv.4r8.b2<br/>dis.a4r8.b2<br/>dis.a4r8.b2<br/>dis.a4r8.b2<br/>clib.618.b2<br/>clib.618.b2<br/>cp.66r7.b2<br/>cp.66r7.b2<br/>csg.a5r7.b2<br/>csg.a5r7.b2<br/>csg.a4r7.b2<br/>csg.a4r7.b2<br/>csg.a4r7.b2</pre>   |                                | <pre>tcth8 tctv8 tctv8 tctv8 tctv8 tctv1 tct1 tc11 tc11 tc11 tc11 tc11 tc1</pre>   | Iner<br>Iner<br>CU<br>CU<br>CU<br>CC<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>MoGR  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>1.000<br>0.600<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000  | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8.<br>8 |
| crtph.4r8.b2<br>crtp.4r8.b2<br>dis.4r8.b2<br>dis.4r8.b2<br>dis.4r8.b2<br>cris.4r8.b2<br>cris.4r8.b2<br>cris.4r8.b2<br>cris.618.b2<br>cris.618.b2<br>cris.618.b2<br>cris.617.b2<br>creg.657.b2<br>creg.657.b2<br>creg.657.b2<br>creg.657.b2<br>creg.677.b2<br>creg.677.b2<br>creg.677.b2  |                                | <pre>tctH8 tctv8 tctv8 tctv8 tctv8 tctv1 tc11 tc11 tc11 tc11 tc11 tc9 tc97 tc97 tc97 tc97 tc97 tc97 tc97</pre>   | Iner<br>Iner<br>CU<br>CU<br>CU<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>0.600<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000   | 6.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>0.0<br>127.5<br>141.1<br>143.5<br>40.7<br>90.0<br>0.0<br>134.6  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.            |
| ctph.478.b2<br>ctpv.478.b2<br>diss.a478.b2<br>diss.a478.b2<br>disc.a478.b2<br>disc.a478.b2<br>clis.438<br>clis.438<br>clis.438<br>clis.438<br>clis.438<br>conder7.b2<br>cong.a677.b2<br>cong.a577.b2<br>cong.a577.b2<br>cong.a577.b2<br>cong.a577.b2<br>cong.a577.b2<br>cong.a577.b2<br>cong.a577.b2<br>cong.a577.b2<br>cong.a577.b2   |                                | <pre>tcth8 tctv8 tctv8 tctv8 tctv8 tctv8 tcti1 tcl1 tcl1 tcl1 tcl1 tcl2 tcsg7 tcsg7</pre>  | Iner<br>Iner<br>CU<br>CU<br>CC<br>C<br>MoGR<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>1.000<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000  | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0 |
| crtph.4r8.b2<br>crtp.4r8.b2<br>dis.4r8.b2<br>dis.4r8.b2<br>dis.4r8.b2<br>cris.4r8.b2<br>cris.4r8.b2<br>cris.4r8.b2<br>cris.618.b2<br>cris.618.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2<br>cro.6d7.b2   |                                | <pre>tcth8 tctv8 tctv8 tctv8 tctv8 tctv8 tcti1 tc11 tc11 tc11 tc11 tc9 tc97 tc97 tc97 tc97 tc97 tc97 tc97</pre>  | Iner<br>Iner<br>CU<br>CU<br>CC<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C   | 1.000<br>1.000<br>1.555<br>1.555<br>1.655<br>1.000<br>0.600<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000   | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0 |
| ctph.478.b2<br>ddss.a478.b2<br>ddss.a478.b2<br>ddss.a478.b2<br>ddsc.a478.b2<br>ddsc.a478.b2<br>ddsc.a478.b2<br>ddsc.a478.b2<br>clis.418<br>clis.418<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc.b2<br>ddsc2 |                                | <pre>tctH8 tctv8 tctv8 tctv8 tctv8 tctv8 tcti1 tc11 tc11 tc11 tc17 tcsp7 tcsp7 tcsg7 tcg7 tcsg7 tcsg7</pre>  | Iner<br>Iner<br>CU<br>CU<br>CU<br>CC<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C   | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.600<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000   | 0.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0<br>90.0  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0 |
| tctph.4r8.b2<br>tdts.4r8.b2<br>tdts.4r8.b2<br>tdts.4r8.b2<br>tdts.4r8.b2<br>tdts.4r8.b2<br>tdts.t4r8.b2<br>tdts.t4r8.b2<br>tctls.4.18<br>tctls.4.18<br>tctls.4.18<br>tctls.4.18<br>tcs.4r7.b2<br>tcsg.4s77.b2<br>tcsg.4s77.b2<br>tcsg.4r7.b2<br>tcsg.4r7.b2<br>tcsg.4r7.b2<br>tcsg.4r7.b2<br>tcsg.417.b2<br>tcsg.417.b2<br>tcsg.417.b2<br>tcsg.417.b2<br>tcsg.417.b2<br>tcsg.417.b2<br>tcsg.417.b2   |                                | <pre>tctH8 tctv8 tctv8 tctv8 tctv8 tctv8 tcti1 tc11 tc11 tc11 tc11 tc17 tcsg7 tcsg7</pre>  | Iner<br>Iner<br>CU<br>CU<br>CU<br>CC<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>MoGR   | 1.000<br>1.000<br>1.555<br>1.555<br>1.555<br>1.000<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000  | $\begin{array}{c} 0 & 0 \\ 90 & 0 \\ 98 & 0 \\ 98 & 0 \\ 98 & 0 \\ 98 & 0 \\ 98 & 0 \\ 98 & 0 \\ 98 & 0 \\ 98 & 0 \\ 98 & 0 \\ 98 & 0 \\ 98 & 0 \\ 141 & 1 \\ 143 & 5 \\ 48 & 7 \\ 98 & 0 \\ 0 & 0 \\ 144 & 5 \\ 141 & 5 \\ 141 & 5 \\ 51 & 4 \\ 138 & 5 \\ 51 & 4 \\ 138 & 5 \\ \end{array}$  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0 |
| tctph.4r8.b2<br>tdfis.a4r8.b2<br>tdfis.a4r8.b2<br>tdfis.a4r8.b2<br>tdfis.c4r8.b2<br>tdfis.c4r8.b2<br>tdfis.c4r8.b2<br>tclib.618.b2<br>tclib.618.b2<br>tcp.66r7.b2<br>tcg.66r7.b2<br>tcg.66r7.b2<br>tcg.64r7.b2<br>tcg.64r7.b2<br>tcg.44r7.b2<br>tcg.44r7.b2<br>tcg.44r7.b2<br>tcg.44r7.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2  |                                | <pre>tctH8 tctv8 tctv8 tctv8 tctv8 tctv1 tc11 tc11 tc11 tc11 tc11 tc2.9 18.9 tcsg7 tcg7 tcg7 tcg7 tcg7 tcg7 tcg7 tcg7 tc</pre>   | Iner<br>Iner<br>CU<br>CU<br>CC<br>C<br>C<br>MoGR<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.600<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000  | $\begin{array}{c} \textbf{0}, \textbf{0} \\ \textbf{90}, \textbf{0} \\ \textbf{127}, \textbf{5} \\ \textbf{141}, \textbf{1} \\ \textbf{143}, \textbf{5} \\ \textbf{40}, \textbf{7} \\ \textbf{90}, \textbf{0} \\ \textbf{0}, \textbf{0} \\ \textbf{134}, \textbf{6} \\ \textbf{46}, \textbf{3} \\ \textbf{130}, \textbf{5} \\ \textbf{0}, \textbf{5} \end{array}$  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0 |
| tctph.4r8.b2<br>tctp.4r8.b2<br>tdis.4r8.b2<br>tdis.4r8.b2<br>tdis.4r8.b2<br>tdis.c.4r8.b2<br>tclis.4.8<br>tclis.b.48<br>tclis.b.618.b2<br>tcp.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2<br>tcg.6dr7.b2  |                                | <pre>tctH8 tctv8 tctv8 tctv8 tctv8 tctv8 tcti1 tc11 tc11 tc11 tc11 tc17 tcsg7 tcsg7</pre>  | Iner<br>Iner<br>CU<br>CU<br>CU<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>MoGR<br>C<br>MoGR<br>C<br>MoGR<br>C<br>MoGR<br>C<br>MoGR<br>C<br>MoGR<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.600<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000  | $\begin{array}{c} 0, 0\\ 90, 0\\ 99, 0\\ 99, 0\\ 90, 0\\ 90, 0\\ 90, 0\\ 90, 0\\ 90, 0\\ 90, 0\\ 0\\ 0, 0\\ 141, 1\\ 143, 5\\ 40, 7\\ 90, 0\\ 0.0\\ 134, 6\\ 46, 3\\ 141, 5\\ 51, 4\\ 130, 5\\ 0, 5\\ 0, 6\\ \end{array}$  | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0 |
| tctph.4r8.b2<br>tctp.4r8.b2<br>tdis.a4r8.b2<br>tdis.a4r8.b2<br>tdis.a4r8.b2<br>tdis.c4r8.b2<br>tcli.b.618.b2<br>tcli.b.618.b2<br>tcp.66r7.b2<br>tcg.66r7.b2<br>tcg.66r7.b2<br>tcg.66r7.b2<br>tcg.64r7.b2<br>tcg.64r7.b2<br>tcg.44r7.b2<br>tcg.44r7.b2<br>tcg.44r7.b2<br>tcg.45r7.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcg.617.b2<br>tcl.617.b2  |                                | tctH8<br>tctV8<br>tdi<br>tdi<br>tdi<br>tcli<br>tcli<br>tcli<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcs | Iner<br>Iner<br>CU<br>CU<br>CU<br>CC<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000  | $\begin{array}{c} \textbf{0}, \textbf{0} \\ \textbf{90}, \textbf{0} \\ \textbf{92}, \textbf{0} \\ \textbf{98}, \textbf{0} \\ \textbf{75}, \textbf{141}, \textbf{1} \\ \textbf{143}, \textbf{5} \\ \textbf{48}, \textbf{7} \\ \textbf{98}, \textbf{0} \\ \textbf{0}, \textbf{0} \\ \textbf{134}, \textbf{6} \\ \textbf{46}, \textbf{3} \\ \textbf{138}, \textbf{5} \\ \textbf{98}, \textbf{6} \\ \textbf{98}, \textbf{0} \\ \textbf{6}, \textbf{0} \\ \textbf{6}, \textbf{0} \\ \end{array}$ | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0 |
| crtph.4r8.b2<br>crtp.4r8.b2<br>dis.4r8.b2<br>dis.4r8.b2<br>dis.4r8.b2<br>dis.04r8.b2<br>crib.618.b2<br>crib.618.b2<br>crib.618.b2<br>crib.618.b2<br>cro.6dr7.b2<br>cro.6dr7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.96r7.b2<br>cro.977.b2<br>cro.977.b2<br>cro.977.b2<br>cro.977.b2<br>cro.977.b2  |                                | <pre>tctH8 tctv8 tctv8 tctv8 tctv8 tctv8 tctv1 tcli tcli tcli tcli tcli tcli tcli tcsg7 tc</pre>   | Iner<br>Iner<br>CU<br>CU<br>CC<br>CC<br>MoGR<br>CC<br>CC<br>CC<br>CC<br>CC<br>CC<br>CC<br>CC<br>CC<br>CC<br>CC<br>CC<br>CC   | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.565<br>1.000<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000 | $\begin{array}{c} 0.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 90.0\\ 143.5\\ 46.7\\ 40.7\\ 90.0\\ 134.6\\ 46.3\\ 141.5\\ 50.0\\ 134.6\\ 46.3\\ 141.5\\ 90.0\\ 0.0\\ 0.0\\ 0.0\\ 0.0\\ 0.0\\ 0.0\\ 0.$   | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0 |
| ctph.478.b2<br>ddss.a478.b2<br>ddss.a478.b2<br>ddss.a478.b2<br>ddsc.a478.b2<br>ddsc.a478.b2<br>ddsc.a478.b2<br>ddsc.a478.b2<br>clis.418<br>clis.618.b2<br>cp.d677.b2<br>csg.a677.b2<br>csg.a677.b2<br>csg.a677.b2<br>csg.a677.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg.a477.b2<br>csg   |                                | tctH8<br>tctV8<br>tdi<br>tdi<br>tdi<br>tcli<br>tcli<br>tcli<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcsg7<br>tcs | Iner<br>Iner<br>CU<br>CU<br>CU<br>CC<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>C<br>MoGR<br>C<br>C<br>C<br>I<br>I<br>C<br>C<br>I<br>I<br>C<br>I<br>I<br>C<br>I<br>C<br>I<br>C<br>I<br>C  | 1.000<br>1.000<br>1.565<br>1.565<br>1.565<br>1.000<br>0.600<br>0.600<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000<br>1.000  | $\begin{array}{c} \textbf{0}, \textbf{0} \\ \textbf{90}, \textbf{0} \\ \textbf{92}, \textbf{0} \\ \textbf{98}, \textbf{0} \\ \textbf{75}, \textbf{141}, \textbf{1} \\ \textbf{143}, \textbf{5} \\ \textbf{48}, \textbf{7} \\ \textbf{98}, \textbf{0} \\ \textbf{0}, \textbf{0} \\ \textbf{134}, \textbf{6} \\ \textbf{46}, \textbf{3} \\ \textbf{138}, \textbf{5} \\ \textbf{98}, \textbf{6} \\ \textbf{98}, \textbf{0} \\ \textbf{6}, \textbf{0} \\ \textbf{6}, \textbf{0} \\ \end{array}$ | 0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0.<br>0 |

#### Updates to the NDC section website

| CERN BE-ABP-N                               | IDC Se | ction Webpage  | Q Search   | 🔶 GitLab                                 |  |  |  |  |
|---|--------|--|--|--|--|--|--|--|
| CERN BE-ABP-NDC Section<br>Webpage          |        | Heavy-ion collimation  | ,  | Table of contents<br>Relevant references |  |  |  |  |
| BE ABP NDC Section                          |        |  |  |  |  |  |  |  |
| Team  |        | With the hierarchical design of the LHC collimation system, the c  | ollimation cleaning efficiency                           |  |  |  |  |  |
| Research topics<br>Non-linear beam dynamics | ~      | while the inertactular design of the LFC commator system, the commator localing enclosely depends on the scattering of hadrons from the primary to the retracted secondary collimators.<br>While this concept works well for proton beams, reaching cleaning efficiencies of 99.9999% (or cleaning inefficiencies of $10^{-4}$ ), heavy-ion beam collimation suffers from the fact that nuclear and electromagnetic interactions heavy ions undergo in the collimators can lead to |  |  |  |  |  |  |
| Hadron beam collimation<br>Protons          | ~      |  |  |  |  |  |  |  |
| Heavy lons                                  |        | fragmentation into other atomic nuclei. These fragments, which signficiantly different mass-to-  |  |  |  |  |  |  |
| Crystal collimation                         |        | charge ratio from the main beam, can leave the collimation system and reach the  |  |  |  |  |  |  |
| Hollow electron lenses                      |        | superconducting magnets of the dispersion suppressor where they are subject to strong  |  |  |  |  |  |  |
| LHC Commissioning                           | >      | magnetic fields of up to 8.3T in the LHC. This magnetic field acts as a spectrometer and diverts<br>the particles to amplitudes so large that they ultimately hit the magnet aperture, where their<br>energy is deposited, ultimately risking them to quench. The collimation cleaning inefficiency for  |  |  |  |  |  |  |
| Machine Development<br>Studies              | >      |  |  |  |  |  |  |  |
| Research results                            | >      | heavy ion beams is higher by two orders of magnitude compared to proton beams.   |  |  |  |  |  |  |
| Software tools                              | >      |  |  |  |  |  |  |  |
| Common Resources                            | >      |  | <mark>╫┊╴┲<sub>┇╋╎┆</sub>╹╤╤╽╤╤<sup>╋</sup>╤╤╽</mark> ╤╧ |  |  |  |  |  |
| New joiner space                            | >      |  |  |  |  |  |  |  |
| Useful links                                | >      |  | Aperture .   |  |  |  |  |  |
| Manuals                                     | >      | $\begin{array}{c} 20 \\ 20 \\ 10 \\ 10 \\ 10 \\ 8 \\ 10 \\ 10 \end{array}$   | 3H1+ 208pb82+  |  |  |  |  |  |

